WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Periodic Dam Safety Inspection Report

Leader Lake Dams

Okanogan County, Washington

June 2001
Pub. No. 01-11-008

printed on recycled paper

Periodic Dam Safety Inspection Report

Leader Lake Dams

Okanogan County, Washington

By
Douglas L. Johnson, P.E.
Dam Safety Office Supervisor

Jerald LaVassar, P.E.
Geotechnical Specialist

Water Resources Program
Dam Safety Office

Washington State Department of Ecology
PO Box 47600
Olympia, Washington 98504-7600
(360) 407-6623

July 2001
Pub. No 01-11-008

Periodic Dam Safety Inspection Report

Leader Lake Dams

The dam safety inspection of the Leader Lake Dams and the engineering analyses and technical material presented in this report were prepared under the supervision and direction of the undersigned professional engineers, in accordance with RCW 43.21A.064(2).

Douglas L. Johnson, P.E.
Supervisor
Dam Safety Office
Water Resources Program

Jerald LaVassar, P.E.
Geotechnical Specialist
Dam Safety Office
Water Resources Program

PERIODIC DAM SAFETY INSPECTION REPORT
Leader Lake Dams

Table of Contents

Executive Summary

General

This report contains the results of inspections performed on May 6, 1998 and a subsequent evaluation of Leader Lake Dams performed by the Dam Safety Section (DSS) of the Department of Ecology (Ecology). It presents the findings from the inspection, engineering evaluation and analyses of the facilities, and required remedial actions to correct deficiencies.

The Leader Lake was formed by the construction of a main dam and saddle dam in 1911 to enlarge a natural lake for the purpose of storing water for the irrigation use. The dams are owned and operated by the Pleasant Valley Water Users Association, and are located 5 miles west of the City of Okanogan in Okanogan County. The main dam is 61 feet high and is located at the west end of the lake. The saddle dam is 17 feet high and is located on an arm at the south side of the lake. The lake is primarily filled by a diversion canal from Loup Loup Creek.

Findings

In general, the Leader Lake Dams are well constructed and maintained. The results of the field inspection and engineering analyses indicate that the facility meets current engineering standards for dam design and construction. A few minor operation and maintenance deficiencies were discovered during the inspection that need to be corrected to ensure continued safety at the facility

Hydrologic Adequacy - The hydrologic analysis revealed that the spillway at Leader Lake has ample capacity to store the Probable Maximum Flood, which is the design flood for this facility. The facility can accommodate this flood even with the lake filled to the spillway crest elevation year-round. This provides an adequate level of protection, given the high downstream hazard setting.

Embankment: The embankments did not show surficial signs of deep-seated, slope instability, and minimal seepage was found. A review of past geotechnical engineering reports indicated that the stability of the dams is adequate under static loadings. A seismic risk assessment was performed by the Department of Ecology in 1991 for the Main Dam and Saddle Dam. The area of concern rested primarily with the upstream slope and central portion of the Main Dam. This report concluded that liquefaction could occur, but the likelihood of experiencing sufficient liquefaction-induced settlement that could result in an uncontrolled release of the reservoir was acceptably remote.

We did not revise the seismic analysis at this time, due to a changing understanding of the seismicity in the region and a lack of modeling tools necessary to complete a seismic risk assessment. We are probably still a year away from being able to complete a risk assessment of this project with a suitable level of confidence in its predictions. However, we anticipate that our reanalysis will confirm that the Main Dam still has an adequate factor of safety regarding seismic stability.

Project Operation and Maintenance: The operation and maintenance at Leader Lake is satisfactory for a facility of such importance and high downstream hazard potential. The dams and reservoir have an adequate set of procedures for operation, maintenance and inspection.. However, a few minor changes in operational procedures and in monitoring are needed.

Maintenance Items: At the Saddle Dam: repair animal burrows and runoff erosion on slope. At Main Dam: modify the existing fence-type trash barrier by raising it to a height coincident with the top of the spillway pipe, dewater outlet tower, inspect valves and test operate upstream guard valve.

Emergency Preparedness: The phone numbers in the current Emergency Action Plan should be tested and changed as necessary.

LEADER LAKE DAMS
PROJECT DATA SHEET

1. General

Dam Owner and Operator	Pleasant Valley Water Users Assoc.
Years Constructed	1910 and 1992
Purpose	Irrigation water storage
Downstream Hazard Potential	Main Dam, *High*, Hazard Class 1A Saddle Dam, *High*, Hazard Class 1C

2. Reservoir Data

Watershed	Tallant Creek
Surface Area at Normal Pool Elevation (El. 2273 feet)	185 acres
Active Storage at Normal Pool Elevation	5,900 acre-feet
Maximum Storage at Saddle Dam Crest Elevation (El. 2282 feet)	7680 acre-feet

3. Main Dam

State ID No.	OK49-223
Type	Earthfill w/ hydraulic fill core
Year Completed	1910, modified 1992
Hydraulic Height	61 feet
Crest Elevation	2283.4 feet
Crest Width	24 feet
Crest Length	350 feet
Upstream Slope	upper 10 ft. is 1.75H:1V, rest is 2.6H:1V
Downstream Slope	2.5H:1V
Outlet	18-inch diameter steel pipe w/ upstream slide gates located in outlet tower

4. Saddle Dam

State ID No.	OK49-358
Type	Homogeneous Earthfill
Year Completed	1950
Hydraulic Height	16 feet
Crest Elevation	2282 feet- Low Point
Crest Width	15 feet
Crest Length	410 feet
Upstream Slope	2.5H:1V
Downstream Slope	2H:1V

5. Spillway

Type	8-foot diameter Corrugated Metal Pipe
Location	Left abutment, Main Dam
Discharge Capacity	470 cfs at El. 2282 ft.
Invert Elevation	2273.3 feet

Leader Lake Dams
Periodic Inspection Report

1. Background Information

1.1 Authority and Purpose

Under state law (RCW 43.21A.064(2)), the Department of Ecology has responsibility and authority to inspect the construction of all dams and other works related to the use of water, and to require necessary changes in construction or maintenance to reasonably secure safety to life and property. This report has been prepared in accordance with this statute.

The report presents the results of the inspection and a subsequent safety evaluation of the Leader Lake Main Dam and Saddle Dam. The report provides:

- Background information,
- A description of the project,
- Results of the May 6, 1998 inspection,
- Engineering evaluation and analyses of the design of the project,
- Required remedial actions based on the findings.

1.2 Project Setting

The Leader Lake Reservoir is located about 5 miles west of the City of Okanogan in Okanogan County, near the headwaters of Tallant Creek (Figures 1 & 2). The reservoir covers an area of 185 acres, and serves as an irrigation water supply for orchards owned by Johnny Appleseed, Inc. and the Pleasant Valley Water Users. The dams are owned and operated by the Pleasant Valley Water Users Association (PVWUA). The reservoir is an enlargement of a natural lake, and was formed by the construction of a main dam and saddle dam in 1911. The main dam is 61 feet high and is located at the west end of the lake. The saddle dam is 17 feet high and is located on an arm at the south side of the lake.

The lake is primarily filled by water from Loup Loup Creek, via a 5.7 mile long canal and pipeline system. A small amount of runoff also enters the lake from the upper Tallant Creek watershed. The reservoir is typically filled between October and May, and water is released for irrigation between April and September. The outlet gates at Leader Lake Dam are normally closed in October, and available water flows are diverted until winter freeze-up. Most of the filling occurs in the spring, when all available water flows in Loup Loup Creek are diverted and stored in the reservoir. The reservoir level is held at 2268.0 feet or below between October and March 1. After March 1, the maximum reservoir elevation is increased up to 2273 feet, as inflow permits.

1.3 Project History

The Leader Lake Dams were constructed in 1910. According to a report by CH2M Hill[1], the foundation for the main dam was excavated to rock for the most part. The dam was constructed by placing a series of earth berms at successive elevations at the upstream and downstream limits of the dam, then sluicing material into the central portion of the dam by hydraulic fill methods. The placement of the exterior berms was accomplished by horse-drawn scrapers, using material obtained from the hillside above the dam. The original spillway for this project was constructed on the left abutment of the main dam, and consisted of an open rectangular channel lined with hand-placed rock for most of its length. Because of concerns over erosion of the spillway lining, the water users held the reservoir level below the spillway crest level. Thus, the spillway never discharged during its 76-year life span.

In 1978, the Leader Lake project was inspected by engineers from the Department of Ecology and CH2M Hill under the National Dam Safety Program administered by the US Army Corps of Engineers. The resulting Phase I inspection report[2] stated that the overflow spillway was not adequate to pass the Probable Maximum Flood (PMF), insufficient information was available to assess the embankments' stability, and the outlet conduit condition was unknown. Based on these findings, the following recommendations were made:

- Determine the detailed PMF, and modify the dam as needed.
- Conduct engineering studies to determine the stability of the dam embankments.
- Modify the embankments as required to provide safety as recommended by engineering guidelines.
- Immediately conduct an inspection of the outlet conduit and repair as required.
- Perform routine maintenance work, such as clearing trees and brush from dams.

. In response to this report, in 1986, the Water Users retained CH2M Hill to perform Phase 2 studies and develop plans for the needed repairs to the Leader Lake Dams. A detailed hydrologic analysis revealed that the project could pass the PMF with an 8-foot diameter spillway pipe replacing the existing spillway, and the dam crests raised 5 feet. Geotechnical explorations and analyses indicated that the both dams had adequate stability under static loadings, but liquefiable materials were present in the Main Dam. A subsequent analysis[3] performed by the Dam Safety Section revealed that while liquefaction could occur in a major earthquake, the chances of overtopping failure of the dam were extremely remote, based on the current understanding of seismicity in the region. Thus no seismic modifications were required. Based on these findings, modification plans were developed for the Leader Lake Dams, which entailed installing an 8-foot diameter spillway pipe down the left abutment of the Main Dam, raising the Main Dam crest 5 feet and buttressing the downstream slope, and raising the saddle dam crest 6 feet. The construction of these modifications started in 1991 and was completed in 1992.

2. Project Description and Field Inspection

2.1 Inspection Team

The field inspection of the Leader Lake Dams was performed on May 6, 1998. The Dam Safety inspection team consisted of the following personnel:

Name	**Aspects Covered**
Douglas L. Johnson, P.E.	Coordinator, Hydrology/Hydraulics
Jerald LaVassar, P.E .	Geotechnical

Representatives from the Pleasant Valley Water Users Association present at the inspection included Gordon Grosvenor, Joel Hand, Wayne Norris, and Ken Chalmers. .

2.2 Reservoir

Leader Lake is a reservoir formed by the enlargement of a natural lake and is impounded behind 2 dams. The reservoir is filled by water a diversion canal from Loup Loup Creek, and by runoff from the watershed surrounding the lake. Leader Lake has a surface area of 185 acres at normal maximum pool elevation 2273.0 feet, with a storage volume of 5,900 acre-feet. The outlet gates at Leader Lake Dam are normally closed in October, and available water flows in Loup Loup Creek are diverted until winter freeze-up. Most of the filling occurs in the spring, when all available water flows in Loup Loup Creek are diverted and stored in the reservoir. The reservoir level is held at 2268.0 feet or below between October and March 1. After March 1, the maximum reservoir elevation is increased up to 2273 feet, as inflow permits. The maximum lake level in the past 7 years was about 2274 feet, when the Water Users utilized the spillway to regulate the reservoir elevation. The maximum fill level has been held below the spillway crest the past few years, because the Water Users believed they were not supposed to use the spillway. The minimum lake level is typically reached at the end of irrigation season in late September, at around elevation 2260 feet.

At the time of our inspection, Leader Lake was at elevation 2272.9 feet, which was 0.4 feet below the spillway invert, and 10.5 feet below the crest of the Main Dam. The slopes surrounding Leader Lake are moderate no evidence of instability was noted that could result in a slide large enough to threaten the dam. Thus, reservoir rim stability is not a dam safety concern.

2.3 Embankments, Abutments and Foundation

2.3.1 Main Dam

The Leader Lake Main Dam is a zoned earthfill structure with upstream and downstream shells of compacted silty fill, and a central core of hydraulically placed silty sand. The dam has a maximum height of 61 feet, a crest width of 24 feet, and a crest length of 350 feet. The upstream face of the dam is inclined at 1.75H:1V for the upper 10 feet, and 2.6H:1V for the lower portion. The upstream slope is protected by a layer of riprap. The downstream slope was modified in 1992 by adding fill to flatten the slope to 2.5H:1V and by installing a drainage blanket between the new fill and the old dam in the downstream toe area. A pipe collects seepage from the drain and discharges downstream from the outlet structure.

Our inspection of the Main Dam revealed it to be in excellent condition. The upstream riprap layer was in good condition, and no evidence of wave erosion, slope movement, or displacement was noted on the visible portion of the upstream face. The downstream slope was similarly in good condition, with no evidence of slumps, slides, depressions, or cracking. A minor slump was noted on the left downstream abutment, about midway up the slope, but was judged to be insignificant. No seepage was observed on the downstream face, toe area or abutments. The toe drain discharge pipe was found to be flowing at 6 gallons per minute (gpm). According to Mr. Hand, the seepage flow has been fairly constant at 6 gpm regardless of reservoir level since January 1997, but prior to that time, the flow rate fluctuated between 1 and 5 gpm. This change in flow characteristics occurred at the same time a new watermaster began measuring flows and the toe drain pipe was raised above the creekbed to facilitate measurement.

Our examination of the Main Dam crest revealed no signs of cracks, settlement, sinkholes or depressions. A paved roadway largely covers the crest, and no signs of distress were found in the pavement indicating instability with the dam. The crest was provided with settlement monuments in 1992, and a recent survey of the monuments revealed that minimal settlement or displacement has taken place. It was noted that based on the survey information, the dam crest is actually 0.4 feet higher than the monuments, at elevation 2283.4 feet, due to the thickness of the paved roadway on the surface.

2.3.2 Saddle Dam

The Saddle Dam is a zoned earthfill embankment which has a maximum height of 17 feet, a crest length of 410 feet, and a crest width of 15 feet. The upstream slope is inclined at 2.5H:1V and is protected by a 2 foot thick riprap layer. The downstream slope was extensively widened when the dam was raised in 1992. The added fill provides the saddle dam with a low permeability core and a 12-inch thick drainage blanket to collect and control seepage. The downstream slope is now inclined at 2H:1V.

Our examination of the upstream face revealed no slumps, slides cracks or other signs of instability. The riprap appeared to be providing adequate protection against wave erosion. The dam crest likewise exhibited no stability problems, and a review of the survey monument information revealed no evidence of settlement since 1996. The downstream slope was covered with grass, and no cracks, slumps, slides or depressions were noted. No seepage was noted on the downstream slope and toe area immediately downstream from the dam. A wetland area was present about 150 feet downstream from the dam, but this is probably due to poor drainage rather than seepage from the dam.

2.4 Spillway

The principal spillway at Leader Lake consists of an 8-foot diameter corrugated metal pipe (CMP) on the left (south) abutment of the Main Dam. The spillway is provided with a concrete intake structure that is fitted with vertical metal bars to prevent debris or people from entering the pipe. A fence-like trash collector is also provided across the inlet channel several feet upstream from the pipe entrance. The pipe extends under the dam crest, then passes down the left downstream groin for a total distance of 275 feet. An air vent pipe is provided at the break in slope on the downstream face to aerate the flow and prevent siphoning. At the end of the pipe, a concrete headwall and apron are provided, to prevent headward erosion and downcutting.

Our examination of the spillway revealed it to be in excellent condition. The inlet channel was is good condition, with only minor debris present. The concrete headwall and trashrack appeared to be in excellent shape. We were unable to access the pipe interior due to the bars across the entrance, but viewing down the pipe from each end revealed no obvious problems. The concrete headwall and apron at the downstream end were similarly in good condition. Finally, the riprap channel protection downstream from the apron exhibited no signs of displacement or movement.

2.5 Outlet Works

The outlet works at Leader Lake Dam consist of an upstream concrete box culvert, a gate tower with twin gate valves, a downstream 18-inch steel conduit encased in grout within a concrete box culvert, and a downstream energy dissipator/screening structure. The upstream conduit is rectangular in section, with a width of 30 inches and a height of 20 inches. This conduit extends upstream from the gate tower beyond the upstream toe and into the reservoir. The gate tower is located 40 feet upstream from the dam crest, and has a 4.6 foot inside diameter with a height of 53 feet. Two, 16-inch diameter gate valves are set in line on a 16-inch pipe that passes through the base of the tower. This 16-ich pipe transitions to the original concrete box culverts that extend upstream and downstream from the tower. Downstream from the tower, an 18-inch steep pipe was installed in 1992, and the annular space between the original concrete culvert and the new pipe was sealed with grout. At the downstream toe, between the end of the old concrete culvert and the new discharge structure, the 18-inch pipe was encased in reinforced concrete, with a minimum thickness of 8 inches. The 18-inch pipe discharges into a concrete screening structure. This structure allows irrigation flows to be spilt between a delivery pipeline and discharges directly into the creek (see Drawing C-4).

Since the reservoir was full at the time of our inspection, most elements of the outlet works were submerged, and not inspectable. We were able to examine the upper portion of the outlet tower and valve operators, and both appeared to be in good condition. According to PVWU staff, the upstream valve is always open, and the downstream valve is used to regulate outflow. They reported no problems in operating the downstream valve, but they do not routinely test operate the upstream guard valve. The interior of the tower was submerged by water up to the reservoir elevation and could not be examined. We were also able to examine the concrete discharge structure, and found it to be in good condition. This structure was modified somewhat from the 1991 plans by adding a bifurcation and adding valves at the downstream end, to allow better control of the discharge. All valves, piping and concrete for the discharge structure appeared to be in satisfactory condition.

3. Evaluation and Analyses

3.1 Downstream Hazard Classification

The primary public safety considerations of any dam failure are the potential for loss of life and damage to property in the downstream valley. Washington State uses a classification system to describe the general level of development downstream from a dam, that could be affected by a flood should the dam fail. This classification is used for selecting minimum design levels for the various elements of the facility, such as the flood used to design or analyze the spillway(s). Table 1 below lists the classification system used by the Dam Safety Section.

Table 1. Downstream Hazard Classification

Downstream Hazard Potential	Downstream Hazard Classification	Column 1A Population at Risk	Column 1B Economic Loss Generic Descriptions	Column 1C Environmental Damages
Low	3	0	Minimal. No inhabited structures. Limited agriculture development.	No deleterious materials in water
Significant	2	1 to 6	Appreciable. 1 or 2 inhabited structures. Notable agriculture or work sites. Secondary highway and/or rail lines.	Limited water quality degradation from reservoir contents and only short-term consequences.
High	1C	7 to 30	Major. 3 to 10 inhabited structures. Low density suburban area with some industry and work sites. Primary highways and rail lines.	Severe water quality degradation potential from reservoir contents and long-term effects on aquatic and human life.
High	1B	31-300	Extreme. 11 to 100 inhabited structures. Medium density suburban or urban area with associated industry, property and transportation features.	
High	1A	More than 300	Extreme. More than 100 inhabited structures. Highly developed, densely populated suburban or urban area with associated industry, property, transportation and community life line features.	

Prior to the 1998 inspection, the setting downstream from the Leader Lake Dams was classified as having a *High* downstream hazard potential (Hazard Class 1B) for the Main Dam, and *High* (Hazard Class 1C) for the Saddle Dam. As part of the inspection, the downstream hazard potential was reassessed. This was accomplished by visual inspection of the downstream valley with the aid of topographic maps and a review of the dam breach flood analysis, which was performed in 1994 to develop the Emergency Action Plan. The dam break discharge from a failure of the Main Dam would be 26,200 cubic feet per second (cfs), which would flood at least 60 homes along Tallant Creek down to the Okanogan River. Based on this finding, the downstream hazard classification of 1B for the Main Dam is appropriate.

For the Saddle Dam, a failure would have to take place during a major flood in order for there to be a significant volume stored behind the dam. Assuming the reservoir is at the design flood level of 2281 feet when it fails, the dam break discharge would be on the order of 12,000 cfs. Although many homes in the floodplain would be inundated by natural flooding prior to failure of the Saddle Dam, the additional flooding caused by the dam break would certainly impact more than 10 homes. Therefore, the downstream hazard classification for the Saddle Dam should be upgraded to Hazard Class 1B.

3.2 Hydrology and Spillway Adequacy

A Probable Maximum Flood (PMF) Study[4] of the Leader Lake watershed was completed in 1987 by CH2M Hill to size an overflow spillway and dam crest raise to provide adequate discharge and storage capacity for the PMF. The design storm used in generating the PMF was the Probable Maximum Precipitation (PMP), based on HMR-43[5]. This storm equates to Step 8 of the DSO eight-step design criteria, which represents an annual exceedance probability of 1 in one million or less. This study determined that an 8 foot diameter spillway at elevation 3373 feet, and the dam crests at 2283 feet would be able to handle the warm season thunderstorm PMF safely. However, in order to handle a rain-on-snow cool season PMF, the reservoir would have to be held below elevation 2268 feet between October and March 1st. Since the study was originally completed, the National Weather Service has revised the PMP estimates for the Northwest in HMR-57[6]. Since HMR-57 decreased precipitation estimates significantly in the Leader Lake area, it appeared that the requirement to hold down the reservoir level may be unnecessarily conservative. Thus it was decided to revise the design storm and PMF computations to determine an appropriate operation scheme for the project.

3.2.1 PMP Estimates

The following table compares the new PMP estimates for the Leader Lake watershed with the values used in the 1987 PMF study.

Table 2
Comparison of General Storm PMP Estimates for the Leader Lake Watershed

Duration (hr)	HMR-43 Estimate (in)	HMR-57 Estimate (in)
General Storm		
24	10.4	8.0
72	17.2	12.4
Thunderstorm		
1	7.9	6.7
6	11.2	7.7

The new PMP values represent a 28 % decrease in general storm rainfall at the 72-hour duration, and a 31% decrease in thunderstorm rainfall at the 6-hour duration.

3.2.2 Probable Maximum Flood Computation

The revised hydrologic analysis performed for this inspection utilized the US Army Corps of Engineers HEC-1[7] program to analyze the runoff characteristics for the revised PMF. The total drainage area for the watershed, including the lake was 3.1 square miles. Input data necessary for computing floods produced by the rainfall events included the storm distribution, snowpack, soil infiltration characteristics, and synthetic unit hydrographs. The revised model utilized the same watershed characteristics as the 1987 CH2M Hill study, with the exception that the infiltration rate used was more conservative, 0.10 inches/hour instead of 0.12 inches/hour. The reservoir elevation at the start of both floods was assumed to be at 2273.8 feet, or 0.5 feet over the spillway invert. The revised general storm PMF had a peak discharge of 1834 cfs, and a runoff volume of 1665 acre-feet. The thunderstorm PMF had a peak discharge of 15,430 cfs, with a runoff volume of 1130 acre-feet. Under the revised PMFs, the minimum freeboard on the saddle dam (which is 1 foot lower than the main dam) was 2.6 feet for the thunderstorm, and 2.2 feet for the general storm with snowmelt. Table 3 provides a summary of the revised Probable Maximum Flood Estimates.

Table 3
PMF Computation Summary

Storm Type	Peak Discharge (cfs)	Runoff Volume		Maximum Reservoir Elev. (ft)	Freeboard (feet)	
		Inches	Acre-feet		Main	Saddle
General w/ snowmelt	1,834	10.2	1665	2279.8	3.6	2.2
Thunderstorm	15,430	6.9	1130	2279.4	4.0	2.6

Based on the foregoing, the Leader Lake project can safety handle both the Thunderstorm and General Storm PMF, with ample freeboard on the dams. Also, it is no longer required that the owner to operate the reservoir below 2268 feet between October and March. Instead, the reservoir can be safely operated year-round at or below 2273.8 feet, utilizing the spillway as the control to maintain the elevation.

3.3 Embankment Stability

3.3.1 Static Stability

Main Dam - The static stability of the embankment was evaluated by CH2M Hill for the current embankment cross section, i.e., reflecting the finger drains and buttress added to the downstream face and the over-excavation work on the upstream toe done in 1992. The maximum water surface was set at the normal maximum pool elevation. The analysis yielded a minimum factor of safety against an embankment failure of 1.46. Since this is approximately the accepted minimum factor of safety of 1.5, the embankment stability was considered acceptable. A review of the assumptions used for the soil properties of the embankment and foundations confirmed that conservative values were used. Based on the foregoing, the static stability of the Leader Lake Main Dam is considered satisfactory.

Saddle Dam - CH2M Hill evaluated the stability of the Saddle Dam following the 6-foot crest raise to elevation 2283 feet. The results indicated that the downstream slope was stable under these conditions with a minimum factor of safety of 1.73. The saddle dam was constructed as modeled, and no changes in the geometry have occurred since. Finally, the embankment has performed satisfactory with no stability problems noted. Thus, the Saddle Dam is likewise considered to have adequate static stability.

3.3.2 Seismic Analysis

Main Dam - A seismic risk assessment was performed by the Department of Ecology in 1991 for the Main Dam and Saddle Dam. The Main Dam was of primary concern, as the lower portion was constructed using hydraulic fill methods, and preliminary computations by CH2M Hill indicated that liquefaction of these materials could occur at the dam. The area of concern rested primarily with the upstream slope and central portion of the dam. This report agreed that liquefaction could occur, but the likelihood of experiencing sufficient liquefaction-induced settlement that could result in an uncontrolled release of the reservoir was acceptably remote.

We are confident that a reanalysis of the seismic risk at the dam will demonstrate that it has an acceptable factor of safety. However, we anticipate that our reanalysis, when complete will show a significant increase in our estimation of the probability of experiencing damaging ground motions at the dam. This increase in the estimated risk is anticipated due to a number of factors, as follow:

▪ *Seasonal Vulnerable Period for the Reservoir has been Increased* - It appears that the reservoir is operated in a manner where an elevated pool is maintained over a greater period of the year than was assumed in our 1991 study. Thus, the likelihood of the pool being elevated and thus potentially overtoppable given a seismically-induced lowering of the crest is increased.

▪ *Estimated Seismic Loadings Increased* - The data from the 1994 Northridge and 1995 Kobe Earthquakes have increased estimates of the intensity of ground motions for a given magnitude crustal earthquake. Crustal earthquakes drive the seismic risk in the project area. The widely assumed limiting seismic acceleration for the area inferred from Balanced Rock near Omak Lake has been shown to be inappropriately low. Finally, the National Earthquake Hazards Reduction Program has raised the maximum level of random crustal earthquakes in the region from Magnitude 6¼ to 7.

▪ *Residual Strength Estimates for Soils are Viewed with Less Confidence* – Much of the strength data on the residual strength of soils has been revised in the light of a more rigorous review of the case histories of earthquake failures. This data coupled with an evolving research effort into the behavior of soils has demonstrated the profession was likely too optimistic in our estimation of residual soil strengths.

▪ *More Sophisticated Dynamic Models Have Been Developed* - The foregoing developments have increased the loading and reduced the soil's strength or capacity. Fortunately, advances in modeling have identified areas of gross conservatism in our previous generation of dynamic models. Thus, improved models represent an "effective increase in capacity" that should make up in part for the increased loading.

Unfortunately, DSO staff are currently working to understand and apply the new modeling tools to improve our estimation of the probability of a seismically induced failure of Leader Lake dam. We are probably still a year away from being able to complete a risk assessment of this project that we would have a suitable level of confidence in its predictions. However, as stated previously, we anticipate that our reanalysis will confirm that the Main Dam has an adequate factor of safety regarding seismic stability.

Saddle Dam - The Saddle Dam was constructed as an engineered fill, and due to the relatively high level of density achieved in construction, the embankment has a much lower susceptibility to seismic induced settlement than hydraulic fills. Furthermore, the embankment section is only twice as high as the freeboard at normal high pool. Liquefaction induced settlement of much weaker hydraulic fills have not produced settlement more that 40% of the embankment height. Thus, by inspection, seismic induced settlements of the saddle dam would not significantly encroach on the available freeboard

3.4 Project Operation and Maintenance

The Pleasant Valley Water Users developed and implemented an Operation and Maintenance (O&M) Manual for the Leader Lake Project in 1994. The O&M Manual contains instructions for operation of the reservoir, diversion canal and headworks. As stated previously, the reservoir is restricted to elevation 2268 or below, between October and March. Between March and October, the reservoir is allowed to fill to elevation 2273, but is kept below the spillway invert. Based on the hydrologic analysis described in Section 3.2, the PVWU no longer is required to operate the reservoir level at a restricted level in the winter. Also, the reservoir can now be filled high enough to utilize the spillway to control the lake level, with a maximum elevation 6 inches above the spillway invert, or 2273.8 feet. Thus, the owner should revise the procedures in the O&M Manual to reflect this change.

Another issue covered in the O&M Manual is inspection and monitoring. The only instrumentation at the dam is the toe drain outlet pipe, which discharges at the downstream toe. The information recorded to date shows a discrepancy between recent readings and those prior to January 1997. Since January 1997, the toe drain readings have been listed as constant at 6 gallons per minute. However, this value is not accurately calculated, as the time to fill a one gallon bucket has varied by as much as 3 seconds. In order to achieve more accuracy, it is recommended that a 2 gallon or larger container be used, and the flow rate be calculated to the nearest one-tenth gpm. It is also important to record the reservoir elevation at the time of the reading, as well as the outflow conditions from the low-level outlet, and the weather. The data should be plotted on graph paper periodically to determine if there are any adverse trends developing. These changes should provide more accurate and meaningful data to help determine the long-term seepage conditions of the structure.

Maintenance at the Leader Lake Dams consists primarily of test operating and lubricating valves, maintaining metal surfaces, controlling vegetation and burrowing animals, and clearing debris from the spillway entrance. The dams and appurtenant structures appeared to be very well maintained during our inspection. The only maintenance deficiencies discovered were: a few animal burrows located on the downstream face of the saddle dam, the front gate valve is not annually test operated, and the fence-type trashrack at the spillway entrance does not extend high enough to block debris for the PMF flood elevation.

3.5 Emergency Preparedness

The present EAP for the Leader Lake Project was developed in 1994. A review of the plan revealed that it has adequate procedures for responding to emergencies and notifying appropriate parties of impending or actual failure. The inundation map was prepared in 1994 by the DSO, and is still valid. The only deficiency noted was that a few locations in the plan still list the old Dam Safety Office phone number. All telephone numbers in the EAP should therefore be verified and corrected as necessary.

4. Conclusions and Required Remedial Actions

In summary, the inspection and engineering analyses revealed that the Leader Lake dams were well constructed and maintained facilities, and meet current standards for withstanding floods and earthquakes. A few minor operation and maintenance deficiencies were discovered during the inspection that need to be corrected to ensure continued safety at the facility.

4.1 Maintenance Deficiencies

The following maintenance deficiencies need to be corrected at the dams:

1. The fence-type trashrack in the spillway entrance channel only stands a few feet above the invert elevation of the spillway pipe. If the reservoir level rises above the fence, debris could lodge against the spillway pipe entrance and reduce the discharge capacity. Therefore, the height of the fence trashrack structure should be increased match the crown of the spillway pipe, a total of 8 feet.

2. The animal burrows and erosion gully on the downstream face of the saddle dam should be repaired, by placing fill in the void and thoroughly compacting the material.

3. The gate tower should be dewatered, and the condition of the gate valves should be assessed. The upstream gate valve in the outlet tower should then be test operated annually, to ensure readiness in the event it is needed.

4.2 Operation and Maintenance Manual

The current Operation and Maintenance Manual at Leader Lake should be revised as follows:

1. The revised hydrologic analysis of the watershed indicates that the lake level no longer needs to be restricted in the wintertime in order to handle the design flood. Thus, the Dam Safety Office will no longer require reservoir regulation, other than by flows discharging from the spillway. Thus, the PVWU can modify the reservoir operation plan within the O&M Manual to reflect this change. The maximum allowable reservoir level under normal operation is now 2273.8 feet, with the spillway pipe unobstructed.

2. The method of reading toe drain flows needs to be revised to provide greater accuracy and consistency. To this end, the observer should use a 2 gallon or larger bucket to determine the flow rate, which should be recorded to the nearest one-tenth gallon per minute. The reservoir level at the time of the reading should also be recorded, as well as low-level outlet discharge conditions and weather.

4.3 Emergency Action Plan

The existing EAP for Leader Lake should be reviewed and all phone numbers should be tested and changed as needed. The Dam Safety phone number needs to be updated in a few sections of the plan. The correct number is (360) 407-6623, with a backup beeper number (360) 971-6347.

Appendix A

Figures

Figure 1 – Location Map

Printed from TOPO! ©2000 National Geographic Holdings (www.topo.com)

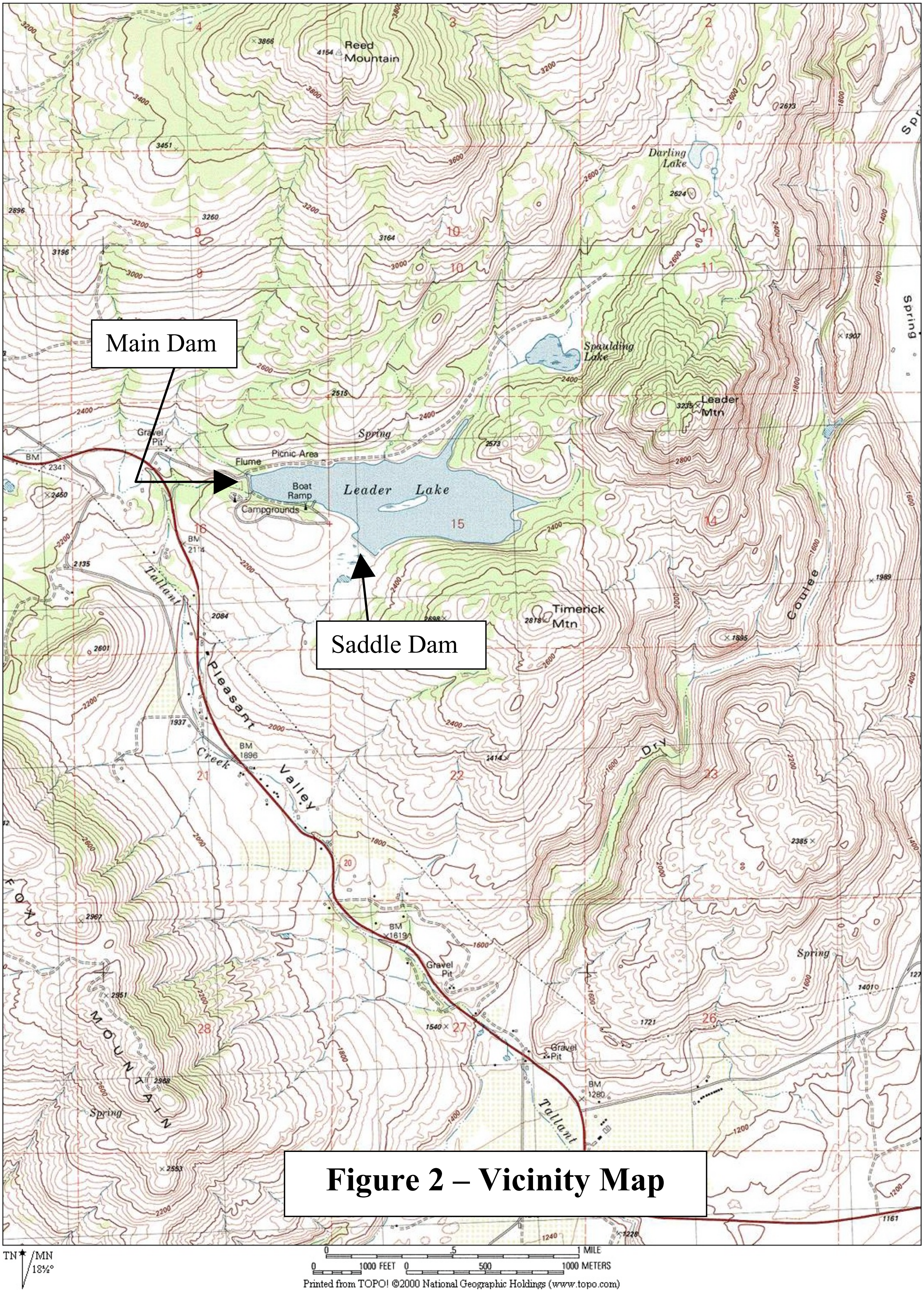

Figure 2 – Vicinity Map

Printed from TOPO! ©2000 National Geographic Holdings (www.topo.com)

Appendix B

Photographs

Photographs not available electronically.

Appendix C

Drawings

Drawings not available electronically.

Appendix D

References

References

1. CH2M Hill, Geotechnical Data Report for Leader Lake Dam, Prepared for Pleasant Valley Water Users Association, April 1987.

2. U.S. Army Corps of Engineers, Phase 1 Inspection Report, National Dam Safety Program, Leader Lake Dams, Malott, Okanogan County, Washington, Seattle, Wash., April 1979.

3. LaVassar, Jerald M. and Ordonez, Gustavo A., Leader Lake Seismic Risk Assessment, Department of Ecology, Water Resources Program, OFTR 91-6, February 1991, Olympia, WA.

4. Bottoroff, Loren, Leader Lake Dam Design Flood, Memorandum Report, CH2M Hill, Seattle, WA, June 18, 1987.

5. U.S. Weather Bureau, Office of Hydrology, Hydrometeorological Report No. 43, Probable Maximum Precipitation, Northwest States, Washington D.C., 1966.

6. U.S. Dept. of Commerce, NOAA, Hydrometeorological Report No. 57, Probable Maximum Precipitation - Pacific Northwest States, Silver Spring, Maryland, 1994.

7. U.S. Army Corps of Engineers, HEC-1 Flood Hydrograph Package, Hydrologic Engineering Center, Davis, California, 1990.